# Exhibit 11

International Price Discrimination in the European Car Market

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# International price discrimination in the European car market

**Frank Verboven***

*Why are car prices so different across European countries? I construct and estimate an oligopoly model to analyze whether international price discrimination can explain the puzzle. Three sources of international price discrimination are considered: price elasticities, import quota constraints, and collusion. The data reveal that international price discrimination accounts for an important part of the observed price differences. Low price elasticities (or domestic market power) are present in France, Germany, the United Kingdom, and especially Italy. Binding import quota constraints on Japanese cars exist in France and Italy. The possibility of collusion cannot be rejected in Germany and the United Kingdom.*

## 1. Introduction

■ Large differences in car prices across countries have been a persistent phenomenon in Europe. A series of studies by the European Bureau of Consumers Unions, BEUC (1981, 1986, 1989, 1992), shows that pretax prices for identical car models may vary by over 90% across countries. Mertens and Ginsburgh (1985) construct a quality-adjusted price index for the whole industry and find that the general pretax price level in Belgium, France, Germany, Italy, and the United Kingdom varies by up to 30%. Although the price differences have somewhat diminished during the past decade (Ginsburgh and Vanhamme, 1989; Mertens, 1990), they remain quite large, and they are not likely to disappear in the near future. Flam (1992) reports that current pretax price differences of 90% for identical car models are still no exception. The question arises why profit-maximizing firms find such large price differences desirable. Do car producers face different costs of operating in the various markets? Or, alternatively, do firms charge different markups in different countries and engage in international price discrimination?

To address these questions, I construct and estimate an oligopoly model that captures the essential determinants of pricing behavior in the European car market. I consider multiproduct price-setting firms, selling differentiated products in geographically

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segmented markets with import quota constraints. The resulting equilibrium pricing equations reveal that the price of each car model in each market equals its marginal cost plus a markup over marginal cost. Price differences across countries may follow either from cost differences or from differences in markups. Markups depend on three factors: the price elasticities implied by the demand model of product differentiation, the possible presence of an import quota against the selling firm, and the possible presence of collusive behavior. These three determinants of markups are at the same time, then, three possible sources for international price discrimination.

I have estimated the model with product-level data using an econometrically tractable method recently proposed by Berry (1994). Several modifications of Berry's method were required to take into account the specific characteristics of the European car market.[1] The data include the prices, sales, and physical characteristics of (almost) all car models sold in 1990 in five European countries: Belgium, France, Germany, Italy, and the United Kingdom. The data reveal that international price discrimination accounts for an important part of the observed price differences in the European car market. First of all, the estimated price elasticities imply that there are substantial cross-country differences in domestic market power. The domestic firms in France, Germany, the United Kingdom, and especially in Italy tend to face much lower price elasticities than the foreign firms. Furthermore, the import quota constraints on Japanese cars are binding in France and Italy. Finally, the possibility of collusion in Germany and the United Kingdom cannot be rejected.

Although the presence of large pretax price differences across countries in the European car market has become well documented, there have been virtually no formal attempts to systematically explain these differences. In their conclusion, Mertens and Ginsburgh (1985) and Flam and Nordstrom (1994) informally conjecture that differences in domestic market power are important, based on their observation of significant cross-country differences in concentration. In reduced-form models, de Melo and Messerlin (1988), Gual (1993), and Flam and Nordstrom (1994) find that import quota constraints influence price differences.[2] Kirman and Schueller (1990) emphasize the role of cost differences in explaining the observed price differences. All these potential explanations are here systematically incorporated in a structural oligopoly model of pricing behavior. The estimated structural parameters make it possible to quantify the importance of international price discrimination through the computation of the implied markups.

In Section 2 I analyze the presence of car price differences across countries in 1990, and discuss some essential structural characteristics that may influence pricing in the European car market. Section 3 develops the formal oligopoly model to be taken to the data. Section 4 discusses the econometric methods and the data. Section 5 provides and interprets the empirical results. Conclusions and suggested extensions follow in Section 6.

## 2. A first look at the European car market

■ In 1990, the total number of new car registrations in the twelve countries of the European Community (now European Union) was approximately 12.1 million, compared to 9.2 million in the United States and 5.1 million in Japan. The number of car

[1] Berry (1994) considered single-product firms in a simpler model of product differentiation without import quota constraints. Potentially more realistic, but computationally burdensome, models of product differentiation have been developed by Feenstra and Levinsohn (1995) and Berry, Levinsohn, and Pakes (1995).

[2] Gual (1993) and Flam and Nordstrom (1994) also show the importance of tariffs to explain price differences. In the present article, I consider only countries in which tariffs are absent.

registrations in the five countries studied in this article, Belgium, France, Germany, Italy, and the United Kingdom, was 10.2 million, covering about 84% of all new car registrations in the EC.

□ **Price differences across national markets.** The presence of car price differences across the various countries in the EC has become well documented since the early 1980s. One of the first studies was done by BEUC (1981), the European Bureau of Consumers Unions. BEUC showed that prices of identical car models may vary by over 90% across countries. These findings were confirmed in subsequent studies: BEUC (1986, 1989, 1992), Monopolies and Mergers Commission (1992), and Commission of the European Communities (1992). For each car model available in the five studied European countries, Figure 1 plots the average pretax price over the five countries (in ECUs) against the maximum percentage price difference and the standard deviation of the price differences. This plot illustrates the presence of large price differences for identical models across countries in 1990. To analyze whether there are also systematic price differences across markets, a "hedonic" price index may be constructed. This is a price index that adjusts for "quality" differences as measured by the observed physical characteristics. Griliches (1971), for example, constructed such an index to study quality-adjusted price changes over time in the American car market. More related to the present study, Mertens and Ginsburgh (1985), Ginsburgh and Vanhamme (1989) and Mertens (1990) have constructed hedonic price indices to compare the quality-adjusted car price level across several European countries.

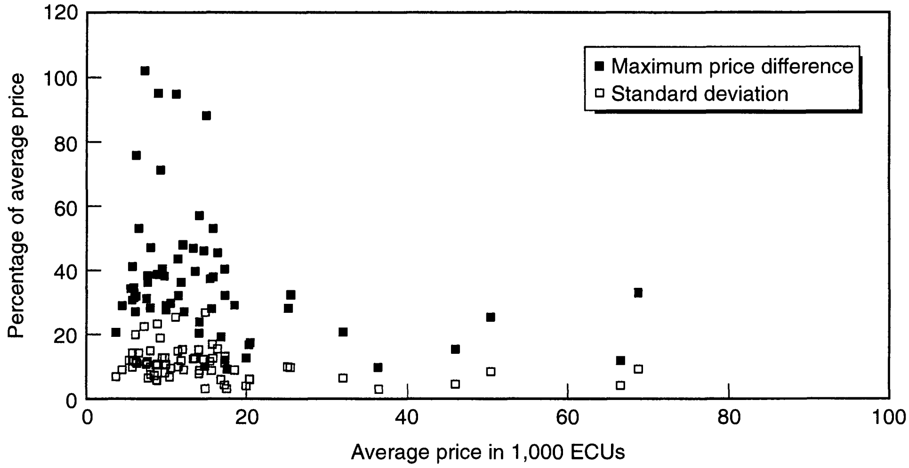
To construct a hedonic price index, assume that the price of a car $j$ in market $m$, $p_{jm}$, is a function of its observed physical characteristics, a vector $w_{jm}$. Conforming to previous studies, assume the following functional form:

$$p_{jm}/(1 + t_m) = \exp(w_{jm}\gamma + \omega_m + \omega_{jm}), \tag{1}$$

where $\omega_{jm}$ is an econometric error term. The term $\omega_m$ is a fixed effect capturing the market-specific part of car prices that cannot be attributed to the observed physical characteristics, $w_{jm}$. Equation (1) is estimated as a simple ordinary least-squares regression. The price $p_{jm}/(1 + t_m)$ of car $j$ in market $m$ is the consumer list price before

FIGURE 1

CROSS-COUNTRY PRICE DIFFERENCES



taxes, converted into ECUs. The vector of physical characteristics, $w_{jm}$, consists of the technical characteristics horsepower, weight, width and height, and a set of country-of-origin dummy variables identifying French, German, Italian, U.K., U.S., and Japanese cars from "other" (mainly East European) cars. The variables are discussed in more detail in the data section below.

The market-specific fixed effects, the $\omega_m$, are estimated using dummy variables with Belgium as the reference country. The $\omega_m$ are then used to construct the hedonic price index, where the index number for market $m$, $p_m$, is given by the formula, $p_m = \exp(\omega_m)$. The obtained hedonic price index is presented in Table 1. It shows that pretax prices in 1990 for cars with identical physical characteristics differ systematically across countries. They are significantly higher in Germany, and especially so in Italy and the United Kingdom, than in Belgium and France. This ranking is roughly consistent with the previous hedonic studies mentioned above. Note that the ranking does not seriously change if dealer discounts are taken into account. Including maximum discounts, as given in Table 1, reduces the estimate of the fixed effect for the United Kingdom by 4%, and increases the fixed effects of the other countries by 1% to 3%, relative to Belgium. The robustness with respect to discounts is consistent with the studies by BEUC, the Monopolies and Mergers Commission, and the EC Commission.

□ **Geographical market segmentation.** The observed cross-country price differences may follow either from systematic differences in the marginal cost of operating in the various markets or from systematic differences in markups, i.e., international price discrimination. A necessary condition for the presence of international price discrimination is the presence of arbitrage costs leading to geographical market segmentation. In the absence of arbitrage costs, consumers would exploit all cross-country differences in markups and buy cars in one country to resell them in another. Several factors do, in fact, contribute to substantial arbitrage costs associated with cross-border trade, leading to geographical market segmentation.

The distribution of cars in the EC falls under Regulation 123/85, which is a block exemption from Article 85(1) of the Treaty of Rome. This regulation was in force from 1985 to 1995 and has recently been extended for another ten years. It authorizes a selective and exclusive distribution system for new cars sold within the EC. This system aims to restrict sales of new cars in the EC to dealers chosen by the manufacturers. As a result, it becomes very difficult for independent wholesalers to buy cars in bulk in one country and resell them in another.[3] Although Regulation 123/85 only authorizes the selective and exclusive distribution of cars on the condition that there are no "excessive" price differences across the markets,[4] this condition has never been enforced in practice. Furthermore, while final consumers in principle have the freedom to purchase their own cars abroad, they encounter considerable legal, administrative, and other obstacles in cross-border purchases. One such obstacle is the requirement of national approval of the imported model. Differences in national standards for safety and environmental reasons often make costly modifications or certification fees necessary.[5] Another obstacle, for the United Kingdom, is the need for right-hand-drive cars. A detailed discussion of various other (administrative) consumer obstacles is provided by BEUC (1992). This discussion then indicates that there are indeed various cross-border arbitrage costs, leading to geographical market segmentation.

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[3] Since the release of a Communication by the EC Commission in 1991, independent wholesalers can engage in cross-border purchases. However, they remain subject to quantitative and other restrictions. See BEUC (1992) for details.

[4] For unspecified reasons, an original specification that price differences should not be more than 12% was later removed. See BEUC (1992) or Davidson et al. (1989).

[5] Since 1993, the European Commission has agreed upon a uniform set of technical requirements.

**TABLE 1** **Characteristics of the European Car Market in 1990**

| | Belgium | France | Germany | Italy | United Kingdom |
|---|---|---|---|---|---|
| Pretax hedonic list price index | 100 | 105 | 110 | 116 | 120 |
| Value-added taxes (in %)[a] | 25 | 25 | 14 | 19 | 24.6 |
| One-year exchange rate change (in %)[b] | 1.7 | 1.0 | .3 | −1.3 | −6.2 |
| Five-year exchange rate change (in %)[b] | 6.3 | −1.4 | 8.9 | −4.6 | −17.3 |
| Maximum dealer discounts (in %)[c] | 11 | 8 | 10 | 10 | 15 |
| Average dealer margin (range in %)[d] | 12–16 | N/A | 16–19 | 14–17 | 16–18 |
| Dealer margin, Opel Astra (in %)[e] | 14 | 14.5 | 16 | 16 | 17 |
| Total sales (in 1,000 units) | 473.5 | 2,309.1 | 3,040.8 | 2,348.2 | 2,008.9 |
| Parallel imports (range in 1,000 units)[f] | N/A | 30–40 | 25–35 | 70–80 | 1–2.5 |
| C1-concentration ratio (in %) | 15.9 | 33.1 | 25.6 | 52.4 | 25.3 |
| C4-concentration ratio (in %) | 53.0 | 76.1 | 61.1 | 77.9 | 64.5 |
| C7-concentration ratio (in %) | 72.9 | 90.0 | 76.7 | 91.8 | 79.0 |
| Domestic market share (in %) | | 60.8 | 67.7 | 52.4 | 55.9 |
| Japanese market share, actual (in %) | 20.0 | 3.3 | 15.9 | 1.9 | 11.5 |
| Japanese market share, quota (in %)[g] | | 3.0 | 15.0 | 1.1 | 11.0 |

[a] In Belgium, 33% for cars over 3000cc. In Italy, 38% for cars over 2000cc. U.K. figure includes 17.5% value-added tax plus a car tax equal to 10% of 5/6 of the factory price. French tax applies since September 1989; before it was 28%.

[b] Relative to the ECU (European currency unit).

[c] Based on interviews by BEUC (1989), estimates for 1989. Roughly consistent with Monopolies and Mergers Commission (1992).

[d] Based on unpublished interviews in 1991 by CECRA, the European Committee for Motor Trades and Repairs (Brussels). Sales weighted minimum and maximum dealer margins on PSA, Fiat, Ford, GM, Rover, and VW cars.

[e] Monopolies and Mergers Commission (1992).

[f] Based on industry sources, collected by BEUC (1989), estimates for 1989. Belgian parallel imports reported to be "small" (mainly some German luxury cars).

[g] Based on Commission of the European Communities (1992). France, Germany, and the United Kingdom: "voluntary" percentage import constraint. Italy: absolute quota constraint under 1%. Belgium: no import quota.

The degree of geographical market segmentation is illustrated in Table 1 by the level of parallel imports, i.e., the goods imported by unauthorized resellers (as defined by Malueg and Schwartz (1994)). Table 1 shows that the level of parallel imports is usually small, relative to the total number of new car registrations in the various markets. The highest level of parallel imports is in Italy, but even here parallel imports are only about 3% of the total number of new car registrations. The low level of parallel imports, despite the high cross-country price differences established above, may be viewed as evidence reinforcing the theoretical arguments given for the presence of geographical market segmentation. International price discrimination cannot then be ruled out as a potential explanation for the observed price differences in the EC car market.

□ **Concentration and international penetration.** A relatively large number of firms are present in the European car market, suggesting a relatively competitive environment. However, given the high degree of geographical market segmentation, it is more

appropriate to consider the number of large firms per country separately. This reveals a rather different picture. In most countries only a few large firms are present. This is illustrated in Table 1 by the C1, C4, and C7 concentration ratios, measuring the market shares of the single largest, the four largest, and the seven largest firms. Compared to Belgium, these concentration ratios are high for Germany and the United Kingdom and especially high for France and Italy.

Furthermore, different firms are present in different markets. Except for Belgium, all countries have large domestic producers: Italy has Fiat (owning Fiat, Alfa Romeo, and Lancia); France has PSA (owning Peugeot and Citroën) and Renault; Germany has VW (owning Volkswagen and Audi), GM (owning Opel), Ford, Mercedes, and BMW; and the United Kingdom has Rover (owning Austin and Rover), Ford, and GM (owning Vauxhall).[6] Table 1 reveals correspondingly large domestic market shares in these countries.

Finally, the non-European firms, consisting mainly of Japanese firms (Honda, Mazda, Mitsubishi, Nissan, Toyota), are present in different degrees in the various countries. The Japanese firms have a large market share in Belgium, a significant market share in Germany and the United Kingdom, and a small market share in France and Italy. The Japanese firms' market share is related to the market share implied by the import quotas. In France and Italy, with very strict import quotas, the Japanese firms' market share significantly exceeds the import quota levels, which is probably due to parallel imports. In Germany and the United Kingdom, with milder "voluntary" export restraints, the Japanese firms' market share only slightly exceeds the quotas.[7]

It is tempting to relate these structural properties of the various national markets to the observed systematic cross-country price differences, as measured by the hedonic (pretax) price index. In Belgium, the low concentration and high international penetration suggest intense competition and low markups. Correspondingly, the price level is relatively low. The other markets, Germany, the United Kingdom, and especially France and Italy, are substantially more concentrated, and they experience less competition from foreign European and non-European producers. This is reflected in a higher price index for France, Germany, Italy, and the United Kingdom. The relatively low price level in France, despite its concentrated and protected market structure, is puzzling. A more important puzzle is the very high price level in the United Kingdom, compared to France and Germany with a similar market structure, and compared to Italy with a more concentrated and protected market structure.

Perhaps cost-side elements should be taken into account to understand the price differences more completely. Tax differences are already incorporated. In some countries firms may face an unobserved extra marginal cost, for example due to the obligated use of catalytic converters and the included roadside assistance in Germany or the United Kingdom. In addition, in some countries the price level (measured in ECUs) may reflect the incomplete pass-through of past exchange rate fluctuations.[8] However, given the depreciation of the pound over the last few years, incomplete exchange rate pass-through would imply a reduction of the ECU price level in the United Kingdom.[9]

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[6] The definition of domestic firms includes the transplants of multinationals, i.e., Ford and GM in Germany and the United Kingdom.

[7] Note that there is actual disagreement about whether import quota constraints exist in Germany. Commission of the European Communities (1992) states that the 15% voluntary export restraint in Germany is fiercely denied by the German industry.

[8] Incomplete exchange-rate pass-through, or local currency price stability, may follow from the presence of imperfect competition (price elasticities) or, in a dynamic setting, adjustment costs. See, e.g., Knetter (1993) and the references therein.

[9] The hedonic study by Ginsburgh and Vanhamme (1989) indicates that this is indeed the case. Hence, before 1990, prices in the United Kingdom were even higher.

Finally, in some countries firms may pay out higher dealer markups, which are usually calculated as a percentage on the pretax consumer list price. Complete data on the dealer markups are not available. There is, however, a common industry wisdom (present in most studies cited above) that dealer markups are especially high in the United Kingdom. This is illustrated in Table 1 by the average minimum and maximum dealer markups of a selected set of firms, and by the dealer markup of the Astra, a car model from GM that has a significant market share in most countries. Another indicator of differences in dealer markups across countries is the maximum discount on the consumer list price allowed by the dealers (Table 1). All other things being equal, high maximum discounts indicate that manufacturers set high consumer list prices allowing for (artificially) high percentage dealer markups.[10]

Mertens and Ginsburgh (1985) also make attempts to relate the observed price differences, as measured by the hedonic price index, to the structural characteristics of the European car market. However, they conclude their article with the following warning (p. 165):

> Clearly a careful study of the various price elasticities in these countries would help in interpreting the results, as would a deeper analysis of product differentiation. The paper does not examine whether price differentials originate in deliberate international producer discrimination policies, or whether this situation is the consequence of collusion among local dealers.

What is needed to more fully understand the observed price differences in the EC is a systematic model that explicitly considers the pricing decisions of the car manufacturers.

## 3. An oligopoly model for the EC car market

■ Rosen (1974) considers a perfectly competitive model with price-taking firms, showing that the hedonic pricing equation (1) may be interpreted as a marginal cost function. According to this competitive interpretation, the estimated fixed effects (the $\omega_m$) would indicate that the marginal costs of operating were the lowest in Belgium and France, and significantly higher in Germany and especially in Italy and the United Kingdom. Kirman and Schueller (1990) argue that substantial cost differences between countries do indeed exist. However, an explanation that is based solely on cost differences is at least suspect. The above description of the EC car market, with its geographical market segmentation and cross-country differences in concentration and international penetration, suggests that firms may be charging different markups in the various countries, engaging in international price discrimination. To systematically investigate this possibility, I use the above information on the EC car market to develop a realistic yet econometrically tractable oligopoly model, covering the competitive interpretation of the hedonic pricing equation as a special case. The oligopoly model allows one to empirically investigate whether the data support a pure cost-side interpretation of the observed car price differences in the EC, or whether in addition international price discrimination is present. The model distinguishes three possible sources of international price discrimination: cross-country differences in price elasticities, import quota restrictions, and collusive behavior.

□ **Pricing.** There are $F$ multiproduct firms operating in $M$ national markets. In each market $m$ a firm $f$ sells a subset, $F_{fm}$, of the $J_m$ car models sold in the market $m$. The sales of a typical car $j$ in market $m$, $q_{jm}(p_m)$ are a function of the consumer price vector

[10] This practice may be the case in the United Kingdom, and could follow from the fact that the country has a high proportion of fleet sales, about 34% of total sales, according to Monopolies and Mergers Commission (1992).

in market $m$, $p_m = (p_{1m}, \ldots, p_{J_m m})$ and not of the price vectors in the other markets.[11] This is based on the assumption of prohibitive arbitrage costs to consumers. Prices are in a common currency, e.g., the ECU. Because a single cross section (for the year 1990) is used, it is not possible to take into account exchange rate fluctuations over time and their possible incomplete pass-through to consumers, as in, e.g., Knetter (1993). The total cost of producing a typical car $j$, $C_j(q_{j1}(p_1), \ldots, q_{jM}(p_M))$, is a function of the sales of car $j$ in the $M$ markets. Firm $f$'s profit is

$$\Pi_f = \sum_{m=1}^{M} \sum_{j \in F_{fm}} p_{jm}^w q_{jm}(p_m) - \sum_{j \in F_{fm}} C_j(q_{j1}(p_1), \ldots, q_{jM}(p_M)), \tag{2}$$

where $p_{jm}^w$ is the wholesale price of a car $j$ in market $m$ received by the firm. The firm's wholesale price, $p_{jm}^w$, may differ from the consumer price, $p_{jm}$, because of value-added taxes imposed by the governments or because of dealer markups. The specific relationship between $p_{jm}^w$ and $p_{jm}$ is modelled as an exogenous relationship. The possible strategic interdependence between firms, dealers, and governments is thus ignored, conforming to most previous empirical studies.[12] The focus is instead on the interdependence among firms themselves.

Firms set the prices of their differentiated products to maximize profit. The assumption of price-setting behavior in the car market is common and consistent with industry wisdom, see, e.g., the discussion of pricing practices by the U.K. Monopolies and Mergers Commission Report (1992).[13] Some firms are not subject to an import quota while other firms are. A firm that is not subject to an import quota simply chooses a wholesale price, $p_{jm}^w$, for every car it markets to maximize its profit, given the prices set by its competitors. A firm that is subject to an import quota solves a constrained profit-maximization problem. In some markets (e.g., in Italy) the constraint specifies that the firm's demand cannot exceed a certain absolute level $D_{fm}$, i.e., $D_{fm} \geq \sum_{j \in F_{fm}} q_{jm}(p_m)$. In other markets (e.g., in France, Germany and the United Kingdom) the constraint specifies that the firm's demand cannot exceed a certain percentage of total market demand $d_{fm}$, i.e., $d_{fm} \geq \sum_{j \in F_{fm}} q_{jm}(p_m)/\sum_{j=1}^{J_m} q_{jm}(p_m)$. Solving the firms' profit-maximization problem generates the following first-order condition for a car $j$ in market $m$, owned by firm $f$:

$$\sum_{k \in F_{fm}} \left( p_{km}^w - \frac{\partial C_k}{\partial q_{km}} - \lambda_{fm}^a \right) \frac{\partial q_{km}}{\partial p_{jm}^w} + q_{jm} = 0 \tag{3a}$$

and

$$\sum_{k \in F_{fm}} \left( p_{km}^w - \frac{\partial C_k}{\partial q_{km}} - \frac{\lambda_{fm}^r}{Q_m} \right) \frac{\partial q_{km}}{\partial p_{jm}^w} + \frac{\lambda_{fm}^r}{Q_m} \frac{Q_{fm}}{Q_m} \sum_{k=1}^{J_m} \frac{\partial q_{km}}{\partial p_{jm}^w} + q_{jm} = 0, \tag{3b}$$

where $Q_m \equiv \sum_{j=1}^{J_m} q_{jm}$, and $Q_{fm} \equiv \sum_{j \in F_{fm}} q_{jm}$. Equation (3a) represents markets with an absolute import quota, and (3b) represents markets with a percentage import quota. In

[11] A related model of multimarket oligopoly with geographical market segmentation is by Bulow, Geanakoplos, and Klemperer (1985).

[12] One exception is the study by Bresnahan and Reiss (1985), who develop and estimate a successive monopoly model.

[13] See Feenstra and Levinsohn (1995) for an empirical approach in which Cournot behavior is also allowed for.

choosing an optimal price for car $j$ in market $m$, firm $f$ takes into account its effect not only on the sales of the car $j$ itself, through $\partial q_{jm}/\partial p_{jm}^w$, but also on the sales of the other cars it owns in market $m$, through the $\partial q_{km}/\partial p_{jm}^w$. If firm $f$ is subject to an import quota, it also takes this into account: the $\lambda_{fm}^a$ and $\lambda_{fm}^r$ are defined as firm-specific variables equal to zero if the firm is not subject to a quota and equal to the respective Lagrange multipliers if the firm is subject to an absolute or a percentage import quota. The larger the Lagrange multiplier, the more binding is the import quota for the firm subject to the quota.

Taken together, there are $J = \sum_{m=1}^{J_m} J_m$ first-order conditions, constituting a Bertrand-Nash equilibrium. Caplin and Nalebuff (1991) have shown the existence of a pure-strategy Nash equilibrium in a fairly general demand model, assuming single-product firms and ignoring import quota constraints. Results from Anderson and de Palma (1992) indicate that for the specific demand model to be developed below, the existence result probably generalizes to multiproduct firms. It is not so clear whether the existence result also generalizes to markets with import quota constraints. Krishna (1989) develops a model with import quotas in which a pure-strategy equilibrium fails to exist due to a discontinuity in the reaction functions. I will here follow the approach taken in Goldberg (1995) and simply assume that a pure-strategy Nash equilibrium exists.

The $J$ first-order conditions (3a) and (3b) can be transformed to obtain $J$ pricing equations, decomposing the price of a car $j$ in market $m$ into its marginal cost and a markup over marginal cost. To see this, define, for each market $m$, a $J_m$-by-$J_m$ matrix, $\mathbf{\Delta_m}$, with a typical element $\Delta_{jkm} = -\partial q_{km}/\partial p_{jm}^w$ if $k$ and $j$ are produced by the same firm, and $\Delta_{jkm} = 0$ otherwise. Similarly, define $\mathbf{q_m}$ as a $J_m$-by-1 vector with typical element $q_{jm}$, and $\mathbf{q_m}^{\mathbf{r}}$ as a $J_m$-by-1 vector with typical element $q_{jm} + (\lambda_{fm}^r/Q_m)(Q_{fm}/Q_m) \sum_{k=1}^{J_m} \partial q_{km}/\partial p_{jm}^w$. It is then possible, for each market $m$, to write the system of $J_m$ first-order conditions in vector notation and rearrange by premultiplying by the $J_m$-by-$J_m$ matrix, $\mathbf{\Delta_m^{-1}}$, the inverse of $\mathbf{\Delta_m}$. This yields the following for each car $j$ in market $m$:

$$p_{jm}^w = \frac{\partial C_j}{\partial q_{jm}} + \mathbf{\Delta_{jm}^{-1} q_m} + \lambda_{fm}^a \tag{4a}$$

and

$$p_{jm}^w = \frac{\partial C_j}{\partial q_{jm}} + \mathbf{\Delta_{jm}^{-1} q_m^r} + \frac{\lambda_{fm}^r}{Q_m}, \tag{4b}$$

where $\mathbf{\Delta_{jm}^{-1}}$ is the $j$th 1-by-$J$ row of $\mathbf{\Delta_m^{-1}}$. Equation (4a) represents markets with an absolute import quota, and (4b) represents markets with a percentage import quota.

The pricing equations (4a) and (4b) reveal that the equilibrium price of each car $j$ in market $m$ is separable into two components: its marginal cost and a markup over marginal cost. Both cost differences and markup differences may in principle be responsible for price differences across car models and across markets. To the extent that price differences across markets come from differences in markups, there is international price discrimination. The markups reveal that there are at least two sources of international price discrimination. First, there may be cross-country differences in price elasticities. Markups are inversely related to the firms' perceived price elasticities of demand, entering through the set of own- and cross-demand derivatives in $\mathbf{\Delta_{jm}^{-1}}$.[14] Second, there may be differences in import quota constraints, entering through the Lagrange multipliers $\lambda_{fm}^a$ and $\lambda_{fm}^r$. A third source for international price discrimination can

[14] In the standard single-product firm case, a car's relative markup simply equals the inverse of its own price elasticity of demand. In the case of multiproduct firms, a car's relative markup equals the inverse of some measure of the firm's perceived price elasticity of demand.

easily be incorporated in the developed framework: differences in collusive behavior. Collusion may be modelled as the joint-profit maximization of a coalition of firms. The set $F_{fm}$, determining which cross-demand derivatives enter in $\mathbf{\Delta}_{\mathbf{jm}}^{-1}$, may accordingly be reinterpreted as the set of cars involved in a collusive coalition $f$ in market $m$. It is then possible to model different coalitions in different markets by appropriately defining the sets $F_{fm}$.

□ **Functional forms.** I discuss the functional form of both components of the pricing equation, marginal cost and markup, in turn. An introductory remark applies. I restrict most parameters to be the same across markets, except for the "fixed effects" that allow the constants to vary across markets. These cross-market restrictions make it possible to pool the data, and they facilitate the estimation.

The functional form of the marginal cost in equation (4) is

$$\frac{\partial C_j}{\partial q_{jm}} = \exp(w_{jm}\gamma_w + \gamma_q \ln Q_j + \omega_m + \omega_{jm}), \tag{5}$$

where $w_{jm}$ is a vector of physical characteristics of car $j$ in market $m$. The variable $Q_j \equiv \Sigma_{m=1}^{M} q_{jm}$, the total (world) sales of a car $j$ in all $M$ markets, indicates whether marginal costs are increasing, constant, or decreasing in output.[15] The error term, $\omega_{jm}$, has the economic interpretation of capturing unobserved (to the econometrician) car characteristics that influence the marginal cost of car $j$ in market $m$. Similarly, the fixed effect $\omega_m$ captures unobserved characteristics that systematically influence the marginal cost of all cars operating in market $m$. This may follow from, for example, unobserved national differences in cost-increasing regulations, such as the required use of catalytic converters in Germany. Note that when markups approach zero due to perfect competition, and when $\gamma_q = 0$, the pricing equation reduces to the simple hedonic specification (1).

The specific relationship between the firm's wholesale price, $p_{jm}^w$, and the consumer (list) price, $p_{jm}$, takes the following functional form:

$$p_{jm}^w = p_{jm}/[(1 + t_m)(1 + \tau_m)], \tag{6}$$

i.e., the firm's wholesale price, $p_{jm}^w$, is a fraction of the consumer (list) price, $p_{jm}$. The variable $t_m$ captures the observable percentage deviations of $p_{jm}^w$ from $p_{jm}$, such as value-added taxes.[16] The variable $\tau_m$ is a fixed effect capturing the unobservable (to the econometrician), market-average percentage deviations of $p_{jm}^w$ from $p_{jm}$, in particular dealer markups.[17] The interpretation of $\tau_m$ as unobserved market-specific dealer markups will often be used below. It is consistent with a standard practice by the car manufacturers in the EC. Indeed, as discussed in Monopolies and Mergers Commission (1992), the dealer markups are usually calculated as a percentage on the pretax consumer list price $p_{jm}/(1 + t_m)$.

[15] There is a theoretical problem in formulating a functional form that captures decreasing/increasing marginal cost as a function of world output. A typical car model has different specifications in different markets. World output should influence only the marginal cost of the "base model," i.e., the minimum specification of the model in all markets. For simplicity, I ignored this problem and simply assumed specification (5), as it would be if a car model has the same specification in all markets.

[16] This specification is for notational simplicity. In the actual estimation I allow taxes to differ across cars in the same market, i.e., $t_{jm}$, which is the case for a few models in Belgium and Italy.

[17] This specification would easily generalize to allow for firm-specific effects, i.e., $\tau_{fm}$. However, estimation would then use up too many degrees of freedom.

The functional forms of the own-demand derivatives $\partial q_{jm}/\partial p_{jm}$ and the cross-demand derivatives $\partial q_{km}/\partial p_{jm}$, appearing in the pricing equation through $\mathbf{\Delta}_{\mathbf{jm}}^{-1}$, are derived from a version of the nested logit model. This model of product differentiation aims to capture the essential characteristics of the demand side of the European car market, while remaining econometrically tractable. There are $L_m$ potential consumers located in market $m$, with prohibitive arbitrage costs of travelling to another market. These consumers either buy one of the $J_m$ car models available in market $m$, or they buy an "outside good." The set of car models available in a market $m$ is partitioned into $G_m + 1$ groups, $g = 0, \ldots, G_m$, where group 0 is reserved for the outside good. Each group $g = 1, \ldots, G_m$ is further partitioned in $H_{gm}$ subgroups, $h = 1, \ldots, H_{gm}$. The cars belonging to the same group have in common one discretely measured characteristic, such as "class." The cars belonging to the same subgroup have in common a second discretely measured characteristic, such as country of origin. The nested logit model allows an individual's preferences for a car $j$ in market $m$ to be correlated with other cars from the same subgroup or group. This generates aggregate demand functions with relatively plausible and still econometrically tractable substitution patterns, allowing for the possibility of localized competition between cars from the same subgroup or group. Berry (1994) develops a simplified version of the nested logit model in an oligopoly context. Berry, Levinsohn, and Pakes (1995) develop a more sophisticated but computationally burdensome model. They essentially allow an individual's preferences for a car $j$ in a market $m$ to be correlated with other cars having similar continuously measured characteristics, rather than with other cars sharing the same discretely measured characteristics. Goldberg (1995) adopts a version of the nested logit model using microdata (at the household level). This also generates some extra flexibility on the demand functions. Nevertheless, as shown below, the nested logit model in the present article is already flexible enough to capture the presence of international price discrimination based on cross-country differences in price elasticities.

As derived in more detail in the Appendix, the specific functional form of the aggregate demand for a car $j$ in market $m$, belonging to a subgroup $h$ of a group $g$, is given by

$$q_{jm} = \frac{e^{\delta_{jm}/(1-\sigma_1)}}{e^{I_{hgm}/(1-\sigma_1)}} \frac{e^{I_{hgm}/(1-\sigma_2)}}{e^{I_{gm}/(1-\sigma_2)}} \frac{e^{I_{gm}}}{\sum_{g=0}^{G_m} e^{I_{gm}}} L_m, \tag{7}$$

where $L_m$ is the number of potential consumers located in market $m$, $I_{hgm}$ and $I_{gm}$ are "inclusive values" defined as

$$I_{hgm} \equiv (1 - \sigma_1)\ln \sum_{l \in V_{hgm}} e^{\delta_{lm}/(1-\sigma_1)}, \qquad I_{gm} \equiv (1 - \sigma_2) \ln \sum_{h \in V_{gm}} e^{I_{hgm}/(1-\sigma_2)}, \tag{8}$$

and where $V_{hgm}$ is the set of cars in subgroup $h$ of group $g$ in market $m$, and $V_{gm}$ is the set of subgroups in group $g$ of market $m$. The variable $\delta_{jm}$ measures the "mean utility" from consuming car $j$ in market $m$, i.e., the part of utility that is common to all individuals. Let $\delta_{jm}$ be a function of a vector of physical characteristics, $x_{jm}$, and price $p_{jm}$, as follows:

$$\delta_{jm} = x_{jm}\beta - \alpha\frac{(p_{jm})^{\mu} - 1}{\mu} + \xi_m + \xi_{jm}, \tag{9}$$

where $\xi_m$ is a market-specific fixed effect, and $\xi_{jm}$ is an error term capturing unobserved

characteristics influencing $\delta_{jm}$. Using the demand equation (7), the demand derivatives for each car $j$ in market $m$ can now be calculated (see Appendix) and substituted into pricing equation (4).

The nested logit model generates several testable hypotheses that may be taken to the data. As shown by McFadden (1978), the nested logit model is consistent with random-utility maximization for $0 \leq \sigma_2 \leq \sigma_1 \leq 1$. If both $\sigma_1$ and $\sigma_2$ are zero, an individual's preferences are uncorrelated across all cars sold in market $m$, resulting in the simple logit model with symmetric (nonlocalized) competition across cars in market $m$. If only $\sigma_1$ is positive and $\sigma_2$ is zero, individual preferences are only correlated across cars from the same subgroup, resulting in localized competition between cars from the same subgroup. If in addition $\sigma_2$ is positive, individual preferences are also correlated across cars from a different subgroup within the same group. If $\sigma_2$ approaches $\sigma_1$, preferences are equally correlated across all cars belonging to the same group.[18] Anticipating the results below, the data will favor a specification in which groups are defined by class (mini and small, medium, large, executive, luxury, and sports), and subgroups are defined by country of origin (domestic versus foreign cars) within a given class. The estimates will reveal a particularly strong correlation of preferences for cars from the same country of origin within a given class. The resulting strong localized competition will be reflected in the presence of strong domestic market power.

## 4. Econometric considerations and data

■ The model to be estimated consists of pricing equation (4) and demand equation (7), with the appropriate substitutions using (5), (6), (8), and (9). I estimated the model using the nonlinear three-stage least-squares estimator (NL3SLS) of Gallant and Jorgenson (1979). This is an estimator for a system of simultaneous, nonlinear, implicit equations. In particular, the NL3SLS estimator allows the error terms, $\omega_{jm}$ and $\xi_{jm}$, to be correlated. Such a correlation may be expected given that unobserved physical characteristics may influence both marginal cost and demand. Furthermore, the NL3SLS estimator takes into account the possible endogeneity of variables such as sales and prices, $q_{jm}$ and $p_{jm}$, through appropriately chosen instrumental variables. Details of the NL3SLS estimator, and of the quasi-likelihood ratio test used for hypothesis testing, are found in Gallant and Jorgenson (1979).

Before the NL3SLS estimator can be used, a computational problem must be resolved. The error terms, $\omega_{jm}$ and $\xi_{jm}$, enter nonlinearly in the pricing equation (4) and the demand equation (7). To avoid the need for computationally burdensome simulation methods, the demand and pricing equations are therefore first transformed in such a way that the error terms enter linearly. This idea was proposed by Berry (1994), in a more simple version of the nested logit model and with single-product firms. The transformations are given in the Appendix. For simplicity, it is assumed that the multiproduct firms only take into account the cross-demand derivatives of the cars they own in the same subgroup.[19] This yields the following model, first for demand, then for pricing, that is taken to the data:

[18] Furthermore, if $\sigma_1$ approaches one, cars in the same subgroup become perfect substitutes. If in addition $\sigma_2$ approaches one, cars in the same group become perfect substitutes.

[19] Firms typically do not own cars from different subgroups (country of origin) within the same group. Furthermore, the cross-demand derivatives with respect to cars from different subgroups or groups were found to be extremely small. In a previous version of the article, Verboven (1994), I experimented with the cross-demand derivatives with respect to cars from different subgroups or groups, and showed that they hardly made any difference.

$$\ln(q_j/L_m) = \ln[1 - Q_m/L_m] + \sigma_1 \ln(q_j/Q_{hgm}) + \sigma_2 \ln(Q_{hgm}/Q_{gm}) + x_{jm}\beta - \alpha \frac{(p_{jm})^\mu - 1}{\mu} + \xi_m + \xi_{jm} \tag{10}$$

and

$$\ln p_{jm} + \ln(1 - m_{jm}) = w_{jm}\gamma + \gamma_q Q_j + \ln(1 + t_m) + \tau_m + \omega_m + \omega_{jm}, \tag{11}$$

where $m_{jm}$, to be interpreted below, is given by

$$m_{jm} \equiv \frac{p_{jm}^{-\mu}}{\alpha} \frac{1 - (1 - \sigma_1) \sum_{k \in F_{fm} \cap V_{hgm}} \left(1 - \left(\frac{p_{km}}{p_{jm}}\right)^{1-\mu}\right) q_{km} r_{hgm}}{\frac{1}{1 - \sigma_1} - \sum_{k \in F_{fm} \cap V_{hgm}} q_{km} r_{hgm}} + (1 + t_m)(1 + \tau_m)\lambda_{fm} p_{jm}^{-1} \tag{12}$$

and

$$r_{hgm} \equiv \left(\frac{1}{1 - \sigma_1} - \frac{1}{1 - \sigma_2}\right)\frac{1}{Q_{hgm}} + \frac{\sigma_2}{1 - \sigma_2}\frac{1}{Q_{gm}} - \frac{1}{L_m}, \tag{13}$$

where $Q_{hgm} \equiv \Sigma_{j \in V_{hgm}} q_j$, $Q_{gm} \equiv \Sigma_{h \in V_{gm}} Q_{hgm}$, and where $\lambda_{fm} \equiv \lambda_{fm}^a$ in markets with absolute import quotas and $\lambda_{fm} \equiv (\lambda_{fm}^r/Q_m)(1 - Q_{fm}/L_m + Q_{fm}/Q_m)$ in markets with relative import quotas. The error terms $\omega_{jm}$ and $\xi_{jm}$ indeed enter linearly in these transformed equations. Note, however, that several parameters enter nonlinearly. To obtain good initial values of the parameters, I first estimated a simplified version of the model with $\mu = 0$ and with $-m_{jm}$ as an approximation for $\ln(1 - m_{jm})$.

To estimate a specification with collusion, the set of cars belonging to the same joint-profit-maximizing coalition should be specified. I specify a coalition as the set of all cars belonging to the same subgroup. The specification to be estimated is then the straightforward analog to (11). Because cars within a subgroup turn out to be relatively close substitutes, in contrast to cars from different subgroups, this specification seems to capture most of the potential collusion fairly well. To formally test for the presence of collusion, a general specification was estimated, nesting specifications (11)–(13) and the analogous collusive specification as two special cases. Details for the test are found in the Appendix.

□ **Identification problems.** The pricing equation (11)–(13) reveals some identification problems. It is not possible to separately identify the market-specific fixed effects $\omega_m$ or the multipliers $\lambda_{fm}^a$ or $\lambda_{fm}^r$ from $\tau_m$. The market-specific fixed effects, which are estimated using market-specific dummy variables, should therefore be interpreted with care. They reflect both cross-country differences in the marginal cost of operating in the various countries ($\omega_m$) and cross-country differences in percentage deviations of the wholesale price from the consumer price ($\tau_m$). Similarly, the Lagrange multipliers should be interpreted with care. They are identified only up to a factor $(1 + \tau_m)$. A high estimate of the multipliers may therefore partly reflect a high $\tau_m$. The inability to obtain a separate identification for $\tau_m$ makes it impossible to accurately compute the absolute wholesale markups received by the firms, i.e., $p_{jm}^w - \partial C_j/\partial q_{jm}$. Fortunately, the relative wholesale markups can easily be computed from the estimates, despite the

identification problems. Indeed, it may be verified that the relative markup for a car $j$ in market $m$ equals

$$\frac{p^w_{jm} - \partial C_j/\partial q_{jm}}{p^w_{jm}} = m_{jm}, \tag{14}$$

where $m_{jm}$ is defined by (12) and can easily be computed from the estimates. The estimates of the relative wholesale markups can then be used to quantify the presence of international price discrimination.

To estimate the Lagrange multipliers (multiplied by $(1 + \tau_m)$), I assume that $\lambda^a_{fm} = \lambda^a_m$ and $\lambda^r_{fm} = \lambda^r_m$ for all Japanese firms subject to the import quota in market $m$.[20] The Lagrange multipliers are then estimated using dummy variables identifying the Japanese cars operating in market $m$. There is a potential identification problem because these dummy variables may also capture some unobserved marginal costs that are specific to firms of Japanese origin.[21] To have an idea of the importance of this identification problem, I also estimated a Lagrange multiplier for Japanese firms selling in Belgium, even though there is no import quota against Japanese cars in that country. I will interpret an insignificant estimate of the Lagrange multiplier for Belgium as evidence that the estimated Lagrange multipliers for the other countries capture the effect of the quota constraint rather well.

□ **The choice of appropriate instrumental variables.** I assume that the vectors of physical characteristics $w_{jm}$ and $x_{jm}$ are exogenous and consequently orthogonal to the error terms $\omega_{jm}$ and $\xi_{jm}$. This exogeneity assumption is the main identification assumption for estimation of the pricing and the demand equations. The assumption seems reasonable in the short run, because firms cannot quickly adjust the characteristics of their cars marketed. In the long run, when firms can choose the characteristics of their cars, this assumption may be more problematic.

Prices and market shares are endogenous and correlated with the error terms $\omega_{jm}$ and $\xi_{jm}$, even in the short run. This is because they are simultaneously determined in the Bertrand-Nash equilibrium. In homogeneous-goods models of supply and demand, instruments are readily available: there are generally enough exogenous variables that affect marginal cost and not demand, and exogenous variables that affect demand but not marginal cost. In the present model with product differentiation, most exogenous variables, the observed physical characteristics, affect both marginal cost and demand. Indeed, it is even possible that $w_{jm} = x_{jm}$, in which case no traditional instruments can be used. Fortunately, there are other instruments available. Because the pricing equation holds for all cars simultaneously, constituting a Nash equilibrium, the physical characteristics of each car's competitors are correlated with its own price and demand. Consequently, (functions of) these variables may be used as instruments. Pakes (forthcoming) and Berry, Levinsohn, and Pakes (1995) discuss the general question of how to obtain efficient instruments when any functions of the competitors' characteristics are potential candidates. I use their results to include the following instruments: the *elements of the vectors of exogenous variables $x_{jm}$ and $w_{jm}$, the average of the elements* of $x_{jm}$ and $w_{jm}$ across other cars owned by the same firm, and the average of the elements

[20] Following Goldberg (1995), one may interpret this as an assumption that the Japanese government allocates the quotas such that the shadow price of the constraint is equalized across firms.

[21] Goldberg (1995) could reduce this identification problem, because some of the Japanese firms sell cars that are both subject and not subject to quotas. Note that in my model the identification problem is slightly reduced under relative import quotas, because in this case the Lagrange multipliers are interacted with the variables $Q_{fm}$ and $Q_m$.

of $x_{jm}$ and $w_{jm}$ across other cars not owned by the same firm. The precise elements of the vectors $x_{jm}$ and $w_{jm}$ are discussed in detail in the data discussion below. I added the following instrument to the list just mentioned: the number of dealers per firm in each country. This variable may be viewed as exogenous at the pricing stage, and at the same time highly correlated with prices and sales.

□ **The data.** The data consist of almost all available base car models in five European countries: Belgium, France, Germany, Italy, and the United Kingdom. Only models with extremely low market shares are omitted. This gives a sample of 512 observations in 1990. All data are from publicly available sources.[22]

The vectors of physical characteristics, $w_{jm}$ and $x_{jm}$, affecting the marginal cost and demand, contain the same elements and may be summarized in two categories. The first category consists of the technical characteristics horsepower, weight, width, and height. Horsepower, weight, and height (measuring aerodynamics) jointly determine the performance variables "speed" and "acceleration." Both width and weight capture "safety." Width and height capture "size" or "comfort." The technical characteristics enter $x_{jm}$ logarithmically, so that their coefficients may be interpreted as elasticities. The second category of physical characteristics in $w_{jm}$ and $x_{jm}$ consists of country-of-origin dummy variables. The coefficients of French, German, Italian, U.K., U.S., and Japanese cars are to be interpreted relative to the "other" cars, mainly East European. An interaction dummy reflects a systematic disadvantage to foreign firms. The country-of-origin variables in the vector $w_{jm}$ capture unobserved differences in the marginal cost of producing cars of a given origin, e.g., due to differences in productivity across countries. The country-of-origin variables in the vector $x_{jm}$ capture unobserved differences in tastes for cars of a given origin. In addition, the country-of-origin variables in both $w_{jm}$ and $x_{jm}$ may capture differences in cost-increasing and demand-reducing trade restrictions imposed against cars from certain countries. The coefficients of the dummy variables cannot identify whether cost/taste differences or differences in trade restrictions are important. Nevertheless, the inclusion of these dummy variables is necessary to avoid biased estimates of the other coefficients.

The nested logit model divides the set of cars into groups and subgroups. I define groups according to their class and subgroups according to their country of origin, although a model with the reverse definition was also estimated. There are seven classes: mini, small, medium, large, executive, luxury, and sports. This classification is based on common industry and marketing classifications in Europe.[23] To evaluate this classification, I checked whether the classes may be interpreted as discrete variables capturing the cars' continuous physical characteristics. I compared the cars' physical characteristics horsepower, weight, width, and height across the various classes. It turned out that the range of characteristics of cars from one class did not generally overlap with that of cars from other classes. The only exception were the classes mini and small. I therefore treated these as one single class, so that a total of six separate classes remains. The classes defined this way may then be viewed as a first proxy for the underlying continuous physical characteristics mentioned above. Groups are split into two subgroups according to country of origin: domestic cars and foreign cars. A

[22] These sources are: *l'Argus de l'Automobile et des Locomotions, Autogids, Auto Moto Revue, Journal de l'Automobile, Katalog der Automobil Revue, MVRIS, Nieuwe tot het Verkeer Toegelaten Voertuigen, Notiziario Statistica, Tatsachen und Zahlen aus der Kraftsverkehrswirtschaft, World Motor Vehicle Data.* I consulted these sources at the libraries of FEBIAC (Brussels) and CCFA (Paris).

[23] These classifications can be found in, for example, *l'Argus de l'Automobile et des Locomotions,* and in the EC Commission car price differential report. The classification in Goldberg (1995) for the American car market seems to be similar, although the labels of the classes differ somewhat: subcompacts, compacts, intermediate, standard, luxury, and sports.

domestic car is defined as a car that is produced domestically. According to this definition, GM and Ford are domestic cars in Germany and the United Kingdom. Japanese cars are generally treated as foreign cars in all European countries. The exception is the Nissan Primera/Bluebird. Because Nissan started with the production of these cars in the United Kingdom in the 1980s, I treated them as U.K. cars in the United Kingdom, but as Japanese cars elsewhere.[24] The other domestic firms were described in detail in Section 2.

All prices are list prices, converted into ECUs using period average market rates. Recall that the wholesale prices appearing in the pricing equation are treated as a (partly unobserved) fraction of the list prices through (6). Ideally, the consumer prices appearing in the demand equation and in the demand derivatives of the pricing equation should be transaction prices instead of list prices. I considered a specification with maximum dealer discounts, given in Table 1, as a proxy for transaction prices, but this hardly affected the results.

Sales are the annual number of new car registrations. To consider whether marginal cost is increasing, constant, or decreasing in total output, EC production data by car model are available. Unfortunately, these figures are of little help for the production levels of the Japanese car models, which are mainly produced outside of Europe. For consistency I therefore use an alternative measure of total production per car model. For each car model $j$ owned by firm $f$, I multiply the share of car $j$'s sales in firm $f$'s sales, using the data on the five markets, i.e., $\Sigma_{m=1}^{5} q_{jm}/\Sigma_{m=1}^{5} Q_{fm}$, by the total (world) production of firm $f$, for which data are available. This measure of total world production per car model (drastically) assumes that the share of a car $j$'s sales in firm $f$'s sales using the data in the five markets is representative for the whole world. I experimented with alternative measures of world production, such as the total sales of car $j$ in the five markets under study. The estimate of the parameter $\gamma_q$ and most other parameters was robust with respect to both measures, although some of the country-of-origin dummy variables (especially the Japanese) were affected.

The number of potential consumers in each market $m$, $L_m$, may in principle be estimated, as in Greenstein (1994), using market-level data that determine $L_m$, such as population, income, or the total demand for cars—a durable good—in previous periods.[25] Because only five markets are considered, I choose to keep $L_m$ as a known variable. I follow Berry, Levinsohn, and Pakes (1995) and set $L_m$ equal to the total number of households in the economy, assuming that each household is a potential buyer of a new car in every year. I also considered an alternative specification in which $L_m$ equals only 25% of the households. This alternative specification assumes that only 25% of the households are potential buyers of a new car; the other households only consider buying a car on the second-hand market (in which they are likely to repurchase their own car). It turned out that the empirical results were robust to alternative specifications of $L_m$, due to a low estimate of the substitution toward the outside good.

## 5. Empirical results

■ Groups are defined according to their class (with one of the groups being the outside good), and subgroups according to their country of origin, foreign or domestic. I used the quasi-likelihood ratio test of Gallant and Jorgenson (1979) to test for several alternative specifications of the nested logit model, all of which were rejected at traditional 5% significance levels, as discussed in detail in Verboven (1994). First, the data rejected

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[24] This is because it is impossible to trace down the origin of the Nissan, United Kingdom or Japan, in the other countries.

[25] In a more sophisticated model, dynamic aspects of durable good competition may be explicitly incorporated.

the special cases of both the competitive, hedonic pricing model with zero markups, and the simple logit model with nonlocalized competition ($\sigma_1 = \sigma_2 = 0$). Second, the data rejected a more sophisticated version of the nested logit model, with an extra nest indicating whether to buy a car from a "high" category (collecting the three highest classes) or a "low" category (collecting the three lowest classes). Third, the data rejected a version of the nested logit model with an extra nest (at the top of the tree) indicating whether to buy the outside good or a car from one of the other classes.[26] Fourth, the data rejected an alternative ordering of the nesting structure, in which groups are defined according to country of origin and subgroups according to class. This specification led to an estimate of $\sigma_1$ significantly below $\sigma_2$, an undesirable result in terms of McFadden's random utility maximization. These various rejections are roughly consistent with Goldberg (1995), who uses micro-level data on the U.S. car market. I also estimated a specification in which cars belonging to the same subgroup behave as a collusive coalition. This specification was rejected by the data at a 10% significance level.

□ **The estimates.** Table 2 presents the estimates of the pricing and the demand equation for the unrejected specification of the nested logit in which groups correspond to class and subgroups to country of origin (domestic or foreign). Consider first the estimated coefficients appearing only in the demand equation and not in the pricing equation. Recall that the coefficients on the technical characteristics may be interpreted as elasticities. The elasticity of both horsepower and width have the expected sign and are estimated precisely. Demand is especially elastic with respect to width. Weight and height enter demand insignificantly. This may be explained by the fact that weight and height have an ambiguous impact on their underlying performance variables: weight increases safety but reduces speed/acceleration; height increases size/comfort but decreases speed/acceleration. The significant variables horsepower and width do not have such an ambiguous impact. Country of origin seems to be an important differentiating physical characteristic. Interpreting the country-of-origin variables as capturing differences in taste, consumers have a high preference for German cars, a lower preference for French and European-built U.S. cars, and the lowest preference for U.K., Italian, Japanese, and other (mainly East European) cars. To compare the "net country-of-origin" effect in a given country, one has to add the foreign firm disadvantage effect where appropriate. In France, for example, it may be verified that consumers tend to prefer French cars to German cars once the foreign firm disadvantage effect is taken into account. Of course, as argued in the discussion of the data, the country-of-origin variables may capture not only direct taste differences, but also systematic demand-reducing trade restrictions against certain countries.

Now consider the estimated cost coefficients. The coefficient on production, $\gamma_q = -0.11$, reveals that marginal cost is decreasing in total output, indicating the presence of returns to scale. Increasing production of a car by 10% increases total variable cost by only $(10 - 1.1) = 8.9\%$. The estimate of this coefficient was robust with respect to alternative measures of total world output. Notice that the estimate of $\gamma_q$ is much below (in absolute value) Berry, Levinsohn, and Pakes' (1995) estimate for the U.S. market, which they found implausibly high. Consistent with previous hedonic studies (based on a competitive interpretation), the technical characteristics entering the marginal-cost equation all significantly contribute to marginal cost in the expected

[26] In the specification with the extra nest for the outside good there is one new substitution parameter $\sigma_3$ (in addition to $\sigma_2$ and $\sigma_1$). This parameter allows for a larger substitutability toward a different class than toward the outside good. In the specification without the extra nest for the outside good, the parameter $\sigma_3$ is equal to zero: the outside good is just like another class because of the same substitutability. Estimation of the more general specification showed that $\sigma_3$ is in fact not significantly different from zero.

**TABLE 2** **NL3SLS Estimates of Nested Logit (512 Observations)**

| | $\mu$ | $\alpha$ | $\sigma_1$ | $\sigma_2$ |
|---|---|---|---|---|
| | −0.278 | 71.812 | 0.522 | −0.081 |
| | (.036) | (27.994) | (.062) | (.162) |

Other Parameters

| | Demand Equation | | Pricing Equation | |
|---|---|---|---|---|
| | Estimate | Standard Error | Estimate | Standard Error |
| Fixed effects | | | | |
| France | 0.463[a] | .172 | −0.008[b] | .029 |
| Germany | 0.359[a] | .207 | 0.060[b] | .028 |
| Italy | 0.673[a] | .172 | 0.020[b] | .030 |
| United Kingdom | 1.408[a] | .207 | 0.116[b] | .029 |
| Constant | 152.084 | 65.768 | 7.503 | .272 |
| Foreign firm disadvantage | −1.122 | .146 | 0.081 | .022 |
| Returns to scale | | | −0.116 | .011 |
| Technical characteristics | | | | |
| HP | 2.148 | .441 | 0.075 | .005 |
| Weight | 0.411 | .535 | 0.119 | .094 |
| Width | 13.846 | 1.548 | 1.711 | .165 |
| Height | −0.187 | 1.163 | −0.447 | .126 |
| Country of origin | | | | |
| France | 1.033 | .183 | 0.171 | .027 |
| Germany | 1.805 | .220 | 0.322 | .028 |
| Italy | 0.495 | .0150 | 0.056 | .027 |
| United Kingdom | 0.647 | .188 | 0.052 | .034 |
| United States | 1.187 | .186 | 0.231 | .030 |
| Other country | 0.401 | .137 | 0.105 | .029 |
| Country-specific quotas in Japanese firms | | | | |
| France | | | 826.5 | 248.3 |
| Germany | | | −176.9 | 248.1 |
| Italy | | | 1,820.8 | 293.1 |
| United Kingdom | | | 214.3 | 244.1 |

Note: Estimates of equations (10)–(11), after substituting (12) and (13). Standard errors are in parentheses. For France, Germany, and the United Kingdom, the estimate of $\lambda_m$ is divided by $Q_m$ to generate the same order of magnitude as for Italy.
[a] $\xi_m$ (relative to Belgium).
[b] $\omega_m$ (relative to Belgium).

direction. The country-of-origin dummies all have positive coefficients relative to "other" (mainly East European) countries. German cars have the highest estimated coefficient. Whether the country-of-origin differences are due to differences in productivity across the various countries or to cost-increasing trade restrictions cannot be discerned from the available data. The foreign firm disadvantage effect on cost is significantly positive and large. This indicates that foreign firms operate at a systematically higher cost, possibly due to an unobserved trade barrier. The fixed effects are estimated jointly significantly different from zero. As explained above, in the present model significant estimates of the fixed effects may follow either from systematic differences in the marginal cost of operating in the various markets (i.e., $\omega_m$) or from systematic differences in percentage deviations of $p^w_{jm}$ from $p_{jm}$ (i.e., $\tau_m$), in particular due to dealer markups. A more detailed interpretation of the significant estimates of the fixed effects is given below.

Now consider the coefficients that enter both the demand equation and the pricing equation through the demand derivatives: $\alpha$, $\sigma_1$, $\sigma_2$, and $\mu$. They are all consistent with the restrictions of the nested logit model, stating that $\alpha > 0$, $0 \leq \sigma_2 \leq \sigma_1 \leq 1$, although $\sigma_2$ is actually estimated slightly negative with a high standard error.[27] The estimates of these parameters are responsible for a relatively plausible pattern of own- and cross-price elasticities, in contrast to the elasticities implied by some of the rejected models, such as the simple logit model and the nested logit model with the reverse nesting structure. The own-price elasticities (not shown here) vary between 5 and 15, roughly consistent with estimates for the U.S. car market by Bresnahan (1981), Feenstra and Levinsohn (1995), Goldberg (1995), and Berry, Levinsohn, and Pakes (1995). Domestic cars usually have the smallest own-price elasticity. Intuitively, domestic cars operate in an uncrowded subgroup with little competition, and competition between the domestic cars from the uncrowded subgroups and the foreign cars from the crowded subgroups is relatively weak (because of the significant difference between $\sigma_1$ and $\sigma_2$). This may be due to genuine consumer preferences for domestic products or to a better-established dealer network by domestic firms. Note also that inexpensive cars from low classes tend to have higher own-price elasticities than do expensive cars from high classes. This is due both to the fact that lower classes are more "crowded" with competitors than high classes and to the significantly negative estimate of $\mu$. The pattern of cross-price elasticities is also intuitive. A percentage decrease in the price of a car has a relatively high impact on the demand for cars from the same country of origin (domestic or foreign) within a class, a smaller impact on the demand for cars from a different country of origin within the same class, and the smallest impact on the demand for cars from different classes. This pattern of cross-price elasticities follows partly from the formulae implied by the nested logit model and partly from the data that favored one specific version of the nested logit model. First, the nested logit formulae for the price elasticities, given by (A4) in the Appendix, show that a percentage price decrease has a higher impact on the demand for cars belonging to the same subgroup than for cars belonging to different subgroups or groups. Second, the data favored one specific version of the nested logit model, with groups defined according to class and subgroups according to country of origin within a given class, yielding the above-described intuitive pattern of elasticities. The data rejected other versions of the nested logit model (e.g., with the reverse ordering of the nesting structure), as well as the simple logit model, which would have yielded a counterintuitive pattern of cross-price elasticities.

Finally, consider the Lagrange multipliers. Although they are, as discussed above, only identified up to a factor $(1 + \tau_m)$, interpret them for simplicity in the narrow sense of Lagrange multipliers. A specification (not shown) was estimated with a Lagrange multiplier for Belgium, in which there is no import quota. The estimate of the Belgian Lagrange multiplier was insignificantly different from zero, and did not affect the estimates of the other parameters by very much. As noted above, this fact may be viewed as evidence that the multipliers capture the quota constraints fairly well, rather than other elements systematically influencing the marginal cost of Japanese firms. The Lagrange multipliers are significantly positive for France and Italy, indicating that the tight import quota constraints are indeed binding in these countries.[28] The Lagrange multipliers for the United Kingdom and Germany, with less tight import quotas, are insignificant.

[27] The imprecise estimate of $\sigma_2$ may be due to the choice of instruments. Without the instrumental variables method, $\sigma_2$ was estimated significantly positive.

[28] The estimates of the Lagrange multipliers in markets where there is a percentage quota constraint were divided by $Q_{fm}$. This gave numbers of the same order of magnitude as the multipliers in markets with absolute quota constraints, so that comparison is easier.

□ **The presence of international price discrimination.** Do the estimates of the price elasticities and the import quota constraints reveal something about the presence of international price discrimination? To answer this question I have computed the relative wholesale markups of the various cars in the various markets, as given by (14). Table 3 presents the estimates of the relative markups for selected cars based on the estimates in Table 2. These cars were selected because they represent all product classes and the countries of origin. The first striking finding is the firms' ability to charge substantially higher markups on their cars sold domestically than on their cars sold abroad. In this sense, domestic firms can be said to price discriminate against the consumers of their home market. As extreme examples, compare the high markups of the Fiat Uno, Tipo, and Croma in Italy to the much lower markups of Fiat elsewhere. Similarly, contrast the markups of the Renault 5 and 19 in France with the markups in other countries. Formally, the high significance of $\sigma_1$, in interaction with the sales variables $q_{jm}/Q_{hgm}$, is responsible for this result. Intuitively, there is strong domestic market power as implied by the estimated price elasticities. Domestic firms operate in uncrowded subgroups, segmented from the more crowded subgroups consisting of the foreign firms. Moreover, the domestic firms often own several (in the case of Fiat, all) car models in

**TABLE 3** **Relative Markups of Selected Cars (in %)**

| Model | Belgium | France | Germany | Italy | United Kingdom |
|---|---|---|---|---|---|
| Fiat Uno | 7.6 | 8.7 | 9.8 | 21.7 | 8.7 |
| Ford Fiesta | 8.0 | 8.9 | 10.5 | 9.5 | 11.7 |
| Nissan Micra | 8.1 | 23.1 | 8.9 | 36.1 | 12.5 |
| Renault 5 | 8.0 | 10.4 | 8.4 | 8.8 | 8.4 |
| Fiat Tipo | 8.4 | 9.2 | 9.0 | 20.8 | 9.1 |
| Ford Escort | 8.5 | 9.5 | 8.9 | 8.9 | 11.5 |
| Renault 19 | 8.9 | 13.0 | 9.2 | 9.5 | 9.0 |
| Toyota Corolla | 9.7 | 19.6 | 13.0 | 24.2 | 13.6 |
| VW Golf | 9.3 | 10.3 | 12.2 | 11.0 | 10.0 |
| Lancia Dedra | 9.1 | 9.9 | 9.2 | 21.8 | 9.8 |
| Mazda 626 | 9.8 | 19.3 | 13.0 | 21.7 | 13.3 |
| Opel Vectra | 9.3 | 9.5 | 10.7 | 9.2 | 11.8 |
| Peugeot 405 | 9.9 | 13.4 | 10.2 | 9.9 | 11.6 |
| Audi 80 | 10.8 | 11.3 | 14.3 | 12.6 | 10.9 |
| Opel Omega | 10.2 | 10.0 | 11.6 | 10.2 | 12.2 |
| Citroen XM | 11.1 | 14.1 | 12.4 | 12.0 | 11.3 |
| Fiat Croma | 9.0 | 9.6 | 9.7 | 21.2 | 9.8 |
| Mercedes 190 | 14.3 | 14.4 | 17.2 | 15.6 | 12.3 |
| BMW 5-series | 12.5 | 12.4 | 12.3 | 12.7 | 13.0 |
| Mercedes 200 | 15.1 | 15.2 | 17.9 | 16.8 | — |
| Honda Prelude | 15.1 | 19.6 | 17.9 | 20.6 | 17.1 |
| BMW 7-series | 15.7 | 15.7 | 14.7 | 19.0 | 21.5 |

Note: Based on equation (14), using estimates in Table 2.

the already uncrowded subgroups. As mentioned above, the significant segmentation between the domestic and foreign subgroups may be due to genuine consumer preferences for domestic products or to better-established dealer networks by domestic firms. Whatever the underlying reason, the resulting smaller price elasticities for domestic firms are exploited by charging higher markups.

The second important finding in Table 3 is the high relative markups of Japanese cars in countries where the quota constraints are binding. In these countries, the Japanese firms obtain a quota rent: they choose to set higher prices than they would in the absence of the constraint. Note that this does not necessarily mean that the Japanese firms are better off due to the quota constraints. The increase in the Japanese firms' unit profits due to the quota may be offset by the reduction in the total number of cars sold.

As a final remark regarding Table 3, note that the relative markups do not only vary across countries, but also across classes. The high-class cars tend to charge the highest markups. Reading from top to bottom, and ignoring the domestic or Japanese cars, the relative markups roughly increase. The most notable exception is the Fiat Croma, which can charge a high markup only in Italy.

Much of the discussion on the empirical results with regard to international price discrimination may be summarized by one summary statistic: the Lerner index. This index has been commonly used in traditional industry case studies. The Lerner index is defined as the sales-weighted average of relative markups in an industry, or in a "segment" of the industry. In traditional industry case studies, the markups required to calculate the index are taken directly from (unreliable) accounting data. In the present study, the markups are inferred from observed pricing behavior. I present the estimated Lerner indices for the various countries in Table 4. I computed Lerner indices both for the whole market and for different segments of the market, as defined by their class.

Consider first the market-average Lerner indices. These differ substantially across countries. Belgium, with no domestic producer and no import quota constraint, has the lowest Lerner index. France, Germany, and the United Kingdom have an index up to 3% higher. Italy has by far the largest Lerner index: as was clear from Table 3 on selected car models, this is the consequence of both domestic market power, as implied by the estimated price elasticities, and the import quota restrictions. In Italy the domestic firm Fiat is almost a monopoly, as it is the single manufacturer in its subgroup. Furthermore, in Italy the Japanese firms are subject to a tight, and binding, quota constraint of 1%.

**TABLE 4 Lerner Indices, per Segment (in %)**

| Segment | Belgium | France | Germany | Italy | United Kingdom |
|---|---|---|---|---|---|
| Mini and small | 8.1 | 10.4 | 9.5 | 16.4 | 10.2 |
| Medium | 9.2 | 11.5 | 11.3 | 16.1 | 11.0 |
| Large | 9.8 | 12.1 | 12.2 | 15.6 | 11.8 |
| Executive | 10.4 | 13.2 | 11.4 | 14.6 | 12.5 |
| Luxury | 13.4 | 13.4 | 15.9 | 18.8 | 14.2 |
| Sports | 14.4 | 15.3 | 15.2 | 17.5 | 19.9 |
| Whole industry | 9.4 | 11.4 | 11.9 | 16.3 | 11.4 |

Note: Sales-weighted average of relative markups, as calculated on Table 3.

The Lerner indices by class give some interesting further insights. Note first that the Lerner indices are higher for higher classes, with the exception of Italy, where markups follow a perverse pattern. Generally speaking, price discrimination is present in all classes and follows the same pattern as the market-average Lerner index, with the highest markups in Italy and the lowest markups in Belgium. However, the degree of price discrimination turns out to be different in different classes. Price discrimination is more pronounced in the low classes and less pronounced in the high classes. This follows from two factors. First, domestic firms are more able to exploit their domestic market power (low price elasticities) in the low-class segments than in the high-class segments. In Italy, Fiat is very strong in the low- and medium-class segments, but not in the high-class segments. In France, PSA and Renault are stronger in the low- and medium-class segments than in the large-class segments. The exception is Germany, where the domestic producers Mercedes, BMW, and VW (Audi) are strong in the high-class segments. Correspondingly, in Germany markups are especially high in the high-class segments. Second, a binding import quota constraint on a Japanese firm has a stronger effect on the price of its small and inexpensive cars than on its large and expensive cars, as can be seen from the formula for the relative markups (14) using (12). Intuitively, this follows from the fact that the import quota restricts the number of imported cars and not the value of imports. As a result, a Japanese firm attempts to shift its demand from its small to its large and expensive products. In future research, it would be interesting to explore the role of a third possible factor responsible for the more pronounced price discrimination in the low classes: the specific role of cross-border arbitrage costs. It may be expected that cross-border arbitrage is relatively less costly for cars from high-class segments than for cars from low-class segments.

□ **Unexplained price differences.** The above results established the presence of international price discrimination as measured by cross-country differences in relative wholesale markups. Price differences that do not follow from differences in markups are captured by the market-specific fixed effects, to be interpreted relative to Belgium. Note that these fixed effects are substantially smaller than the fixed effects of the hedonic specification (as implied by the hedonic price index in Table 1 and the formula for each index number, i.e., $p_m = \exp(\omega_m)$). The interpretation of the drops in the fixed effects, relative to Belgium, is intuitive and illuminating. Recall that the hedonic specification may be interpreted as the special case of perfect competition with zero markups. The fixed effects in the hedonic specification then took over the effect of an "omitted" markup variable: as shown above, the estimated markups are relatively high in all countries, as compared to Belgium.

Despite their drop, the estimates of the fixed effects for Germany and especially the United Kingdom remain quite large, relative to Belgium. The data reject the restricted model without further effects in the pricing equation at a high significance level. Although the fixed effects have a broad economic interpretation of capturing both systematic differences in the marginal cost of operating in the various countries (through $\omega_m$), and systematic differences in percentage deviations of the wholesale price, $p^w_{jm}$, from the consumer list price, $p_{jm}$ (through $\tau_m$), I find them quite substantial; they deserve a more detailed analysis.

A first potential explanation for the significant estimates of the fixed effects may be the imperfect specification of the price elasticities as implied by the nested logit model. As explained above, the price elasticities are an important explanation of cross-country price differences through their effect on markups. If these elasticities are badly specified, they may not explain the cross-country price differences very well, so that the fixed effects may (partly) take over their role. This was especially the case for the

(rejected) hedonic specification with its perfect competition interpretation, for the (rejected) simple logit specification with its nonlocalized competition, and for the (rejected) version of the nested logit model with the reverse nesting structure. Similarly, a more sophisticated model than the present nested logit model, perhaps Berry, Levinsohn, and Pakes' (1995) or Feenstra and Levinsohn's (1995) model of product differentiation, could capture the price elasticities even better and generate less significant estimates of the fixed effects.

A second potential explanation for the significant estimates of the fixed effects may be a bad specification of the firms' actual behavior. In some countries firms may set prices collusively. Recall that a specification in which collusion is present in all countries was rejected by the data. (It also yielded more significant fixed effects.) I also estimated a specification in which collusion is present in some countries and absent in others. The presence of collusive pricing could not be rejected for Germany and the United Kingdom.[29] The fixed effects may then be interpreted as taking over behavioral differences between the countries. According to this interpretation, there may be a third source for international price discrimination. In addition to cross-country differences in price elasticities and import quota constraints, there may be differences in the degree of collusive behavior. A more detailed analysis as to why there would be differences in behavior across countries is still desirable.

A third explanation for the large and significant fixed effects in Germany and the United Kingdom is that there are indeed several factors in these countries that contribute to large marginal costs, or to large deviations of the list price, $p_{jm}$, from the wholesale price price, $p_{jm}^{w}$. Taxes have already been included and therefore cannot be an explanation of the fixed effects. Transportation costs are probably no explanation either. None of the five countries considered is located extremely far from the others. Furthermore, in a reduced-form model, Gual (1993) found that transportation costs could not explain price differences. Incomplete exchange rate pass-through may in principle explain part of the fixed effects. In a country with past exchange rate appreciations, prices (expressed in a common currency such as the ECU) will increase relative to the prices in the other countries, if foreign producers incompletely pass through the appreciation into local prices. Incomplete pass-through might explain the relatively high fixed effect in Germany, given the appreciation of the deutsche mark over five years. However, as already mentioned in Section 2, incomplete pass-through certainly cannot explain the very high fixed effect in the United Kingdom, given the past depreciations of the pound. The high estimate of the fixed effect in both Germany and the United Kingdom may follow from the obligated use of catalytic converters and from the inclusion of warranties and roadside assistance. These cost determinants were not taken into account as characteristics in the marginal cost specification. Though they are difficult to measure, the Commission of the European Communities (1992) estimates that these elements may account for up to an extra 10–15% of the price of a car in Germany and the United Kingdom. The high estimate of the fixed effect in the United Kingdom might also follow from the cost-increasing right-hand-drive regulation. However, the same study indicates that this accounts only for about 1% of the extra cost.[30] Moreover, this extra cost is likely to enter fixed (development) costs rather than marginal costs.[31]

[29] These results should be interpreted with care. It was not possible to allow for the possibility of collusion in all countries simultaneously. I therefore restricted the specification in Belgium to noncollusive behavior. A further analysis, with a larger data sample, is called for.

[30] Commission of the European Communities (1992) has calculated that the extra cost for right-hand drive equals roughly 100 ECU per car. For a representative car of 10,000 ECU, this is only 1% of the price.

[31] The right-hand-drive regulation may of course still have an indirect effect through an increase in arbitrage costs.

The high estimate of the fixed effect in the United Kingdom may finally follow from the presence of systematically higher dealer markups in that country. These are calculated as percentages on the pretax list prices. As explained in Section 2, there is a common industry wisdom that dealer markups are especially high in the United Kingdom. Unfortunately, complete data on dealer markups are not available. A direct proxy is given in Table 1 by the market-average dealer markups and the Opel Astra dealer markup. These figures suggest that dealer markups are indeed higher in the United Kingdom. An indirect proxy for dealer markups is the maximum discount on the list price allowed by the dealer.[32] All other things being equal, high maximum discounts may indicate that manufacturers set high list prices, allowing for (artificially) high percentage dealer markups. According to this reasoning, the high maximum discounts in the United Kingdom seen in Table 1 may reflect high dealer markups on the list price allowed by the manufacturers.[33] I used the alternative proxies for systematic differences in dealer markups to reestimate the model. The resulting estimate of the fixed effect for the United Kingdom indeed becomes less significant.

To obtain a more complete understanding of the role of the fixed effects, it would be desirable to collect data over a larger time horizon in future research. If the fixed effects really capture systematic cross-country differences in marginal costs and in deviations of $p_{jm}^{w}$ from $p_{jm}$, then one might expect them to be not too volatile over time.

## 6. Conclusions and extensions

■ The observed price differences in the European car market have been puzzling to many economists and policy makers. In this article I have used an oligopoly model to analyze to what extent the presence of international price discrimination, as measured by cross-country differences in relative wholesale markups, can explain the puzzle. Three sources for international price discrimination are considered: cross-country differences in price elasticities, differences in quota regimes, and differences in the degree of collusive behavior. My empirical results establish the presence of international price discrimination. Large differences in price elasticities are estimated, indicating the presence of domestic market power. The domestic firms in France, Germany, the United Kingdom, and especially Italy tend to face much lower own-price elasticities than the foreign firms. Significantly binding quota constraints on Japanese firms are found in France and Italy. The possible presence of collusive behavior cannot be rejected for Germany and the United Kingdom. The empirical results are encouraging and suggest two specific topics for further research on price differences in the European car market.[34]

□ **More detailed data.** The collection of additional data could generate additional insights in our understanding of the price differences. Collecting detailed data on country-specific dealer margins and dealer discounts and on country-specific demographics is a first important way to proceed. In addition, it would be desirable to collect data over a longer time horizon, say the period 1970–1995. Several facts indicate that this period has been far from stable. A detailed analysis would provide a good test for the

[32] These data were available from two independent sources: BEUC (1989) and Monopolies and Mergers Commission (1992).

[33] Of course, the reason for such a practice should be further explored. One explanation that is frequently mentioned is the significant presence of "fleet sales" in the United Kingdom (about 34% of the 1990 market).

[34] General topics for further research, recognized in the large literature on the U.S. car market, are the problems associated with the exogeneity assumptions of the physical characteristics of the cars, the modelling of the cost side (excluding plant-level factor prices) and the durability of cars.

robustness of the empirical results. The descriptive studies mentioned in the Introduction suggest a gradual increase in the cross-country price differences during the 1970s and early 1980s, followed by a decrease (Mertens, 1990). During the same period there have been large exchange-rate fluctuations, which producers may or may not have passed through to consumers. A detailed analysis of the exchange-rate pass-through relationship would be desirable to better understand some of the short-term price differences across countries. See Knetter (1993) for some first results on exchange rate pass-through in the car market. Furthermore, there has been a continuous decline of the domestic market shares in several European countries. See, e.g., de Melo and Messerlin (1988). This suggests a gradual decline in domestic market power (as implied by the price elasticities). Moreover, the import quota constraints were introduced in the late 1970s and will only be removed at the end of the century. Finally, the European Commission has taken several measures to better integrate the EC car market and lower cross-border arbitrage costs. Though the deadline for integration was 1992, many of these measures took effect afterward, e.g., the tax harmonization and the uniform set of technical requirements in 1993. The selective and exclusive distribution system, limiting cross-border arbitrage, is an arrangement for the period 1985–1995, but it has been renewed for another 10 years, with some additional specifications to facilitate cross-border trade.

□ **Policy analysis.** The empirical results may be used in policy analysis to analyze the welfare effects of future policy changes. For example, in a theoretical model of the European car market, Davidson et al. (1989) have stressed the ambiguous effects of antidiscrimination regulation on total welfare. Less ambiguous conclusions may be obtained in my theoretical model, augmented with model simulations using the data and the estimates. Similarly, the effects of other policy measures may be analyzed, such as a reduction (or elimination) of the consumer cross-border arbitrage costs, the removal of the import quota constraints, or the harmonization of taxes in 1993.

## Appendix

■ **The nested logit model and the transformed demand and pricing equations.** I specify the version of the nested logit model in more detail, and show how the demand and the pricing equations are transformed such that the error terms $\xi_{jm}$ and $\omega_{jm}$ enter linearly.

In each market $m$ there are $L_m$ potential consumers, with the total number of consumers being $L = \sum_{m=1}^{M} L_m$. Each consumer either buys one car $j$ in market $m$ at price $p_{jm}$, or buys an outside good at a price $p_{0m}$. The outside good guarantees that the total demand for cars is not perfectly inelastic. Indirect utility of consumer $i$ from buying car $j$ in market $m$ is

$$u^i_{jm} = \delta_{jm} + v^i_{jm}. \tag{A1}$$

Indirect utility thus consists of two parts: a mean-utility part equal for all consumers, $\delta_{jm}$, and an individual-specific part, $v^i_{jm}$. Normalize the mean-utility for the outside good in market $m$ to zero, i.e., $\delta_{0m} = 0$, and specify the mean-utility for a car $j$ in market $m$, $\delta_{jm}$, as (9) in the text.[35] Specify the individual-specific part of utility for car $j$ in market $m$, $v^i_{jm}$, as

$$v^i_{jm} = \epsilon^i_m + \epsilon^i_{gm} + (1 - \sigma_2)\epsilon^i_{hgm} + (1 - \sigma_1)\epsilon^i_{jm}, \tag{A2}$$

[35] One may want to check whether this utility specification is consistent with a consumer utility-maximization problem subject to a budget constraint. However, this is not a simple task when goods (cars) are durable. Quoting Goldberg (1995, p. 12), "The expected future income rather than present income, and the life cost of the vehicle instead of the current price should enter the budget constraint." Because of a lack of a satisfying theory of durable goods in an oligopoly context with product differentiation, the flexible specification of price in utility is a useful alternative approach.

where $h$ refers to a subgroup $h$ and $g$ to a group $g$ as given in the text. The distribution of $\epsilon_m^i$ takes an extremely simple form: $\epsilon_m^i = 0$ if consumer $i$ is one of the $L_m$ consumers located in market $m$, and $\epsilon_m^i = -\infty$ if consumer $i$ is not one of the $L_m$ consumers located in market $m$, i.e., there are prohibitive arbitrage costs of travelling to another market. The distributions of $\epsilon_{gm}^i$, $\epsilon_{hgm}^i$, and $\epsilon_{jm}^i$ are standard to the nested logit model: they have the unique distribution such that $\epsilon_{gm}^i$, $(1 - \sigma_2)\epsilon_{hgm}^i + (1 - \sigma_1)\epsilon_{jm}^i)$, and $\epsilon_{gm}^i + (1 - \sigma_2)\epsilon_{hgm}^i + (1 - \sigma_1)\epsilon_{jm}^i)$ have the extreme value distribution. Each consumer $i$ chooses the car that yields the highest utility, $u_{jm}^i$. Aggregating these choices over all consumers, the distributional assumptions on $\epsilon_{gm}^i$, $\epsilon_{hgm}^i$, and $\epsilon_{jm}^i$ generate the well-known nested logit formulae for the conditional choice probabilities, or approximately market shares, $s_{j/hgm}$, $s_{h/gm}$, and $s_{g/m}$, as provided by, e.g., McFadden (1978), Ben-Akiva and Lehrman (1985), and in a representative consumer framework, Verboven (1996). The distributional assumption on $\epsilon_m^i$, guaranteeing no arbitrage, generates a simple formula for the share of market $m$ in the total market, $s_m$, i.e., $s_m = L_m/L$. These formulae can then be substituted in

$$q_{jm} = s_{j/hgm} \cdot s_{h/gm} \cdot s_{g/m} \cdot s_m \cdot L \tag{A3}$$

to obtain the functional form for demand (7) as provided in the text.

Note that $q_{jm}$ does not depend on the prices of cars sold in markets other than market $m$, due to the distributional assumption for $\epsilon_m^i$, guaranteeing no arbitrage. I can therefore drop the subscript $m$ without risk of confusion. The derivation of the appropriate transformation of the demand equation such that the error term $\xi_j$ enters linearly is a rather tedious generalization of Berry (1994). The same is true for the calculation of the own- and cross-demand derivatives and their implied elasticities. I therefore refer to Berry (1994) or Verboven (1994) for these calculations. The resulting transformed demand equation is given by (10) in the text. The own- and cross-price elasticities for a typical car $j$ are

$$e_{jj} \equiv -\frac{\partial q_j}{\partial p_j}\frac{p_j}{q_j} = \alpha p_j^{\mu}\left[\frac{1}{1-\sigma_1} - \left(\frac{1}{1-\sigma_1} - \frac{1}{1-\sigma_2}\right)\frac{q_j}{Q_{hg}} - \frac{\sigma_2}{1-\sigma_2}\frac{q_j}{Q_g} - \frac{q_j}{L}\right] \tag{A4a}$$

$$e_{jk} \equiv \frac{\partial q_k}{\partial p_j}\frac{p_j}{q_k} = \alpha p_j^{\mu}\left[\left(\frac{1}{1-\sigma_1} - \frac{1}{1-\sigma_2}\right)\frac{q_j}{Q_{hg}} + \frac{\sigma_2}{1-\sigma_2}\frac{q_j}{Q_g} + \frac{q_j}{L}\right] \tag{A4b}$$

$$e_{jk'} \equiv \frac{\partial q_{k'}}{\partial p_j}\frac{p_j}{q_{k'}} = \alpha p_j^{\mu}\left[\frac{\sigma_2}{1-\sigma_2}\frac{q_j}{Q_g} + \frac{q_j}{L}\right] \tag{A4c}$$

$$e_{jk''} \equiv \frac{\partial q_{k''}}{\partial p_j}\frac{p_j}{q_{k''}} = \alpha p_j^{\mu}\frac{q_j}{L}, \tag{A4d}$$

where $k$, $k'$, and $k''$ index cars that respectively belong to the same subgroup, to a different subgroup within the same group, and to a different group.

I now derive an appropriate transformation of the first-order conditions, such that the error term $\omega_{jm}$ enters linearly. To simplify, first ignore the $\lambda_f$, capturing import quota constraints. Notice that the multiproduct firms typically do not own cars from a different subgroup (i.e., country of origin) within the same group. Assume furthermore that the multiproduct firm ignores the cross-derivatives of demand for cars sold in different groups: these are typically very small, so this does not affect the results very much. (A previous version of the article experimented with a pricing equation including these cross-derivatives, and found that they indeed hardly made any difference.) Maximizing profits (2) using (6), the first-order condition for a car $j$ then is

$$\sum_{k \in F_{fm} \cap V_{hg}} (1 + t)(1 + \tau)\left(p_k^w - \frac{\partial C_k}{\partial q_k}\right)\frac{\partial q_k}{\partial p_j} + q_j = 0, \tag{A5}$$

where $\partial q_j/\partial p_j$ takes the form implied by (A4a) and the $\partial q_k/\partial p_j$, $k \neq j$ all take the form implied by (A4b). After substituting these demand derivatives, it remains impossible to estimate the first-order condition because there are several marginal cost terms, one for each car $k$ produced by the firm, and hence several error terms. To solve this problem, the first-order condition is transformed. (This is equivalent to solving the inverted matrix in (4).) Substitute the demand derivatives implied by (A4a) and (A4b), rearrange slightly, and divide by $\alpha p_j^{\mu-1} q_j$ to obtain

$$(1 + t)(1 + \tau)\left(p_j^w - \frac{\partial C_j}{\partial q_j}\right)\frac{1}{1-\sigma_1} - \frac{1}{\alpha}p_j^{1-\mu} = \sum_{k \in F_f \cap V_{hg}} (1 + t)(1 + \tau)\left(p_k^w - \frac{\partial C_k}{\partial q_k}\right)q_k r_{hg}, \tag{A6}$$

where

$$r_{hg} \equiv \left(\frac{1}{1-\sigma_1} - \frac{1}{1-\sigma_2}\right)\frac{1}{Q_{hg}} + \frac{\sigma_2}{1-\sigma_2}\frac{1}{Q_g} + \frac{1}{L}. \tag{A7}$$

Because the right-hand side is the same for any car sold by the same firm, this implies that

$$(1+t)(1+\tau)\left(p_j^w - \frac{\partial C_j}{\partial q_j}\right)\frac{1}{1-\sigma_1} - \frac{1}{\alpha}p_j^{1-\mu} = (1+t)(1+\tau)\left(p_k^w - \frac{\partial C_k}{\partial q_k}\right)\frac{1}{1-\sigma_1} - \frac{1}{\alpha}p_k^{1-\mu} \tag{A8}$$

for any car sold by the same firm, so that

$$p_k^w - \frac{\partial C_k}{\partial q_k} = \left(p_j^w - \frac{\partial C_j}{\partial q_j}\right) + \frac{1}{(1+t)(1+\tau)}\frac{1-\sigma_1}{\alpha}(p_k^{1-\mu} - p_j^{1-\mu}). \tag{A9}$$

Substituting this into (A6) for all $k \in F_f \cap V_{hg}$ allows us to substitute out all $\partial C_k/\partial q_k$ terms, so that only $\partial C_j/\partial q_j$ remains, with its corresponding error term $\omega_j$. Substituting and rearranging gives

$$p_j^w = \frac{\partial C_j}{\partial q_j} + \frac{1}{\alpha}p_j^{1-\mu}\frac{1}{(1+t)(1+\tau)}\frac{1-(1-\sigma_1)\sum_{k\in F_f\cap V_{hg}}\left(1-\left(\frac{p_k}{p_j}\right)^{1-\mu}\right)q_k r_{hg}}{\frac{1}{1-\sigma_1} - \sum_{k\in F_f\cap V_{hg}} q_k r_{hg}}. \tag{A10}$$

The second term is effectively the solution to $\mathbf{\Delta}_j^{-1}\mathbf{q}$ in (4). Equation (A10) can be rewritten such that only $\partial C_j/\partial q_j$ appears on the right-hand side. Then one can substitute the functional form of $\partial C_j/\partial q_j$ from (5), and the functional form of $p_j^w$ from (6), and log-linearize both sides so that $\omega_{jm}$ appears linearly, using the approximation $\ln(1+\tau) = \tau$, to obtain (11) without import quotas.

Now consider the first-order condition of firms subject to an import quota. The case of an absolute import quota is straightforward, because $\lambda_f^a$ just adds up to $\partial C_j/\partial q_j$ in pricing equation (4). In the case of a relative quota, a term $\lambda_f^r/Q$ must be added up to $\partial C_j/\partial q_j$. However, there is an additional term, $(\lambda_{fm}^r/Q_m)(Q_{fm}/Q_m)(\Sigma_{k=1}^J \partial q_{km}/\partial p_{jm})$, that must be added up to $q_{jm}(p_m)$. It can be verified that $\Sigma_{k=1}^J \partial q_{km}/\partial p_{jm}^w = -(1+t)(1+\tau)\alpha p_j^{\mu-1}q_j(1-Q/L)$. Steps similar to those for the case without quotas then show that a term $\lambda_f^r/Q(1 - Q_f/L + Q_f/Q)$ must effectively be added up to $\partial C_j/\partial q_j$ to obtain the pricing equation in the case of relative quota.

Finally, consider the case in which firms can collude. Assume that collusive coalitions consist of subgroups. This eliminates most of the competition, as car models from different subgroups are not very close substitutes. A previous version of the article followed a conjectural variation approach. This approach assumes that a firm expects a decrease of its rivals' prices by $\phi$ units, when decreasing its own price by one unit. Unfortunately, the conjectural variation approach—with price-setting firms—does not have the convenient property that it nests both the Bertrand and the collusive outcomes as special cases, an observation similar to Gasmi, Laffont, and Vuong (1992). I therefore consider an alternative approach to nest both models (which de facto turns out to be not too different from the conjectural variations approach anyway). To test whether a firm is maximizing its joint profit (i.e., colluding) with all cars in its subgroup, rather than only with the cars it owns in the subgroup, I estimate the following specification of the pricing equation nesting the two special cases (ignoring quotas):

$$p_j^w = \frac{\partial C_j}{\partial q_j} + \frac{1}{\alpha}p_j^{1-\mu}\frac{1}{(1+t)(1+\tau)}\frac{1-(1-\sigma_1)\left[(1-\phi)\sum_{k\in F_f\cap V_{hg}}\left(1-\left(\frac{p_k}{p_j}\right)^{1-\mu}\right)q_k r_{hg} + \phi\sum_{k\in V_{hg}}\left(1-\left(\frac{p_k}{p_j}\right)^{1-\mu}\right)q_k r_{hg}\right]}{\frac{1}{1-\sigma_1} - (1-\phi)\sum_{k\in F_f\cap V_{hg}} q_k r_{hg} - \phi\sum_{V_{hg}} q_k r_{hg}}. \tag{A11}$$

If $\phi = 0$, a firm considers the effect only on the profits of its own cars in its subgroup. If $\phi = 1$, a firm considers the effect on the profits of all cars in the subgroup. Using a parameter $\phi$ equal for all markets, one may test whether there is collusion in all markets; using market-specific parameters $\phi_m$, one may test whether there is market-specific collusion.

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